



2014 – 2015 Annual Report

I. Introduction

With a continued focus on increasing scientific literacy, the Council on Science and Technology fosters research, education, and intellectual exchange that deepen and broaden understanding, experience, and appreciation of science, technology, engineering, and mathematics (STEM). The Council partners with colleagues in engineering, mathematics, natural sciences, the arts, humanities, and social sciences to explore and promote the relation of STEM with culture and the course of public affairs.

The Council is guided by the following overarching goals to:

- Collaborate with university colleagues to **educate** a STEM-literate society through formal and informal learning experiences.
- Engage in and support **research** that explores STEM education and interdisciplinary collaborations.
- Cultivate **synergies** among a broad and diverse community that bridge STEM, the arts, humanities and social sciences.
- Serve as a **clearinghouse** on innovations that promote excellent, equitable, and innovative STEM research and education.

Throughout the 2014-2015 academic year, the Council collaborated with faculty and students on several courses and initiatives. The following sections provide an overview of the Council's key projects, including the Science and Engineering Education Initiative, educational research, and synergistic activities.

II. Science and Engineering Education Initiative: ST Course Enhancement and Development

In 2010, the Council proposed the Science and Engineering Education Initiative that was passed by faculty vote. The Initiative aims to inspire and prepare all undergraduates, irrespective of their majors, to become scientifically and technologically literate citizens and decision-makers. The primary recommendation of the Initiative was to change the undergraduate general education requirement for the Science and Technology (ST) designate. As a result, undergraduates are required to complete at least two ST-designated courses: at least one with a lab (STL) and the second that may be taken without a lab (STN).

To provide a rich variety of ST offerings, the Council supports faculty in revising and developing science and engineering courses that emphasize the role of science and engineering in society. The Council offers financial resources to faculty developing new and enhancing existing ST-designated courses. During the 2014-2015 academic year, the Council awarded 12 grants to faculty from Anthropology, Architecture, Astrophysics, Center for Information Technology Policy, Civil and Environmental Engineering, Lewis Center for the Arts, Mechanical and Aerospace Engineering, Physics, and Psychology. Two of the grants were made in co-sponsorship with the 250th Fund award.

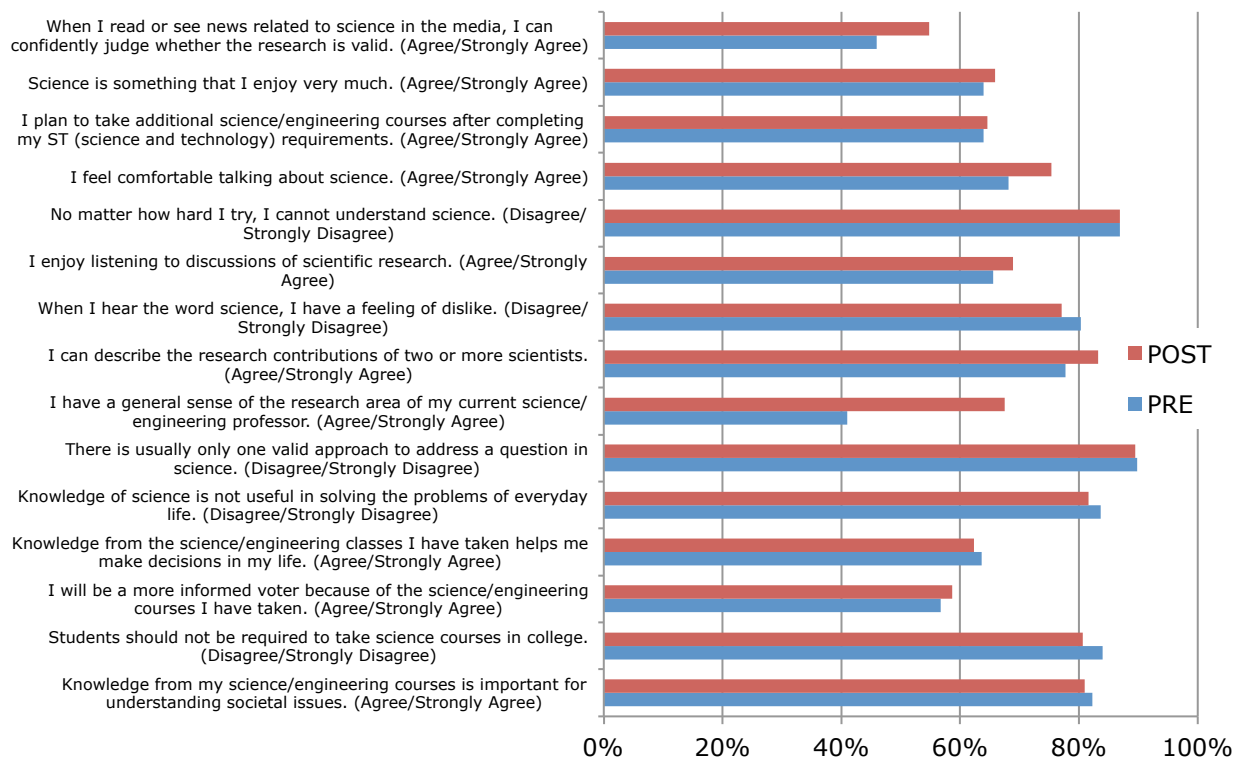
In addition to financial resources and guiding course goals, the Council's four Professional Specialists are available to assist faculty with the enhancement of existing ST-designated courses and the development

of new ST-designated courses. Each Professional Specialist has a terminal degree in a STEM field and additional preparation in student-active pedagogy. Throughout the 2014-2015 academic year, the Professional Specialists supported 20 ST-designated courses. Case studies of their work are provided in Appendix A.

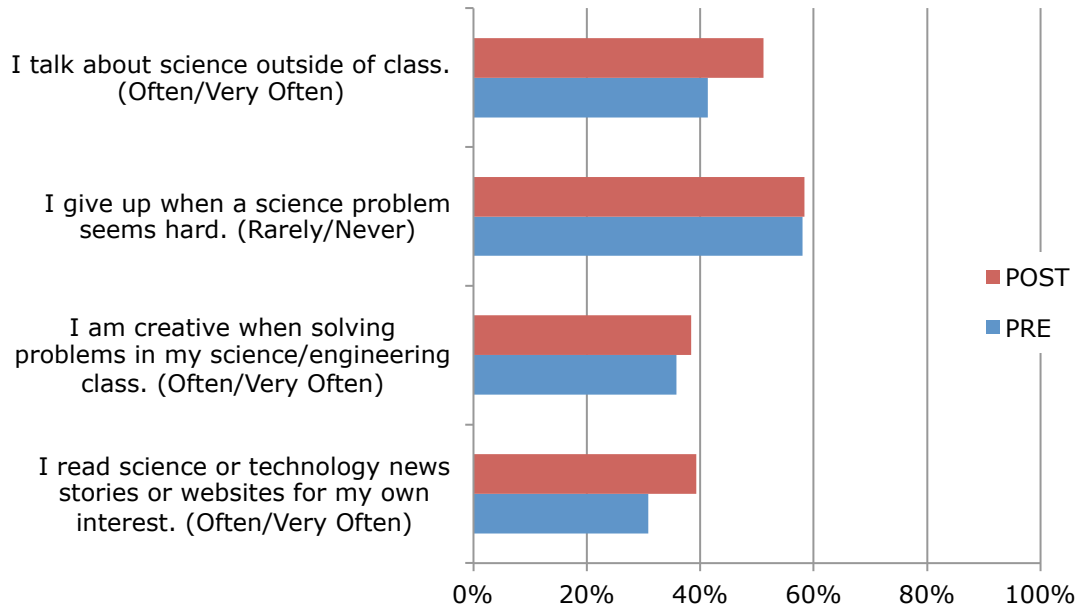
During the 2014-2015 academic year, Princeton University offered 38 ST-designated courses that did not carry a substantial prerequisite and aligned with the spirit and intent of the Science and Engineering Education Initiative. A full list of these courses is available in Appendix B.

The Council administers a survey to understand the extent to which students' attitudes and beliefs towards science change. The survey is administered at the start and end of each semester to students enrolled in the courses identified as being aligned with the Science and Engineering Education Initiative (see Appendix B). The overall results for the attitudes surveys administered in the fall and spring of the 2014-2015 academic year follow. Individual course results vary considerably. Overall, we were interested in the movement of indicators that reflected students' confidence in their scientific/engineering abilities and their personal behaviors related to science/engineering. To ensure that students are reading the survey carefully, some statements are written with a positive sentiment, and we hope to see improvements in the number of students agreeing or strongly agreeing with the statements. Other statements are written with a negative sentiment, and we hope to see an increase in the number of students who disagree or strongly disagree. In all graphs, positive results are closer to 100%.

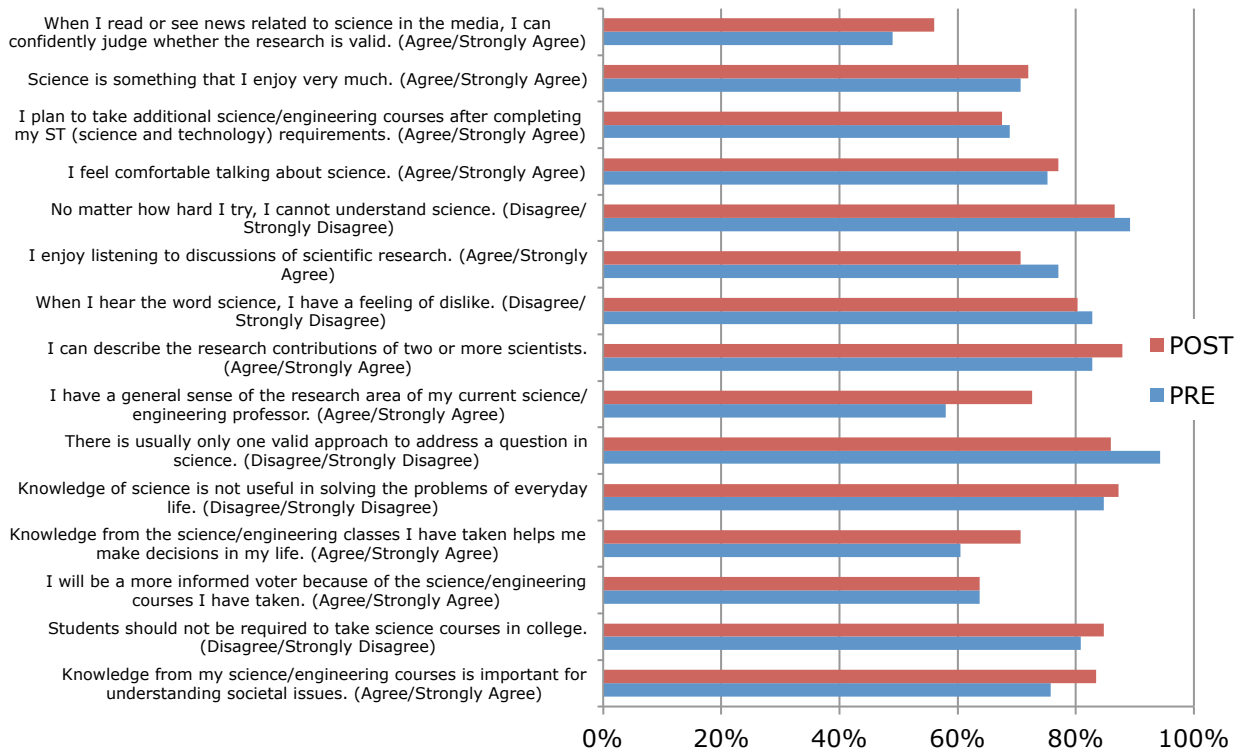
Fall 2014, All ST Courses, N=305



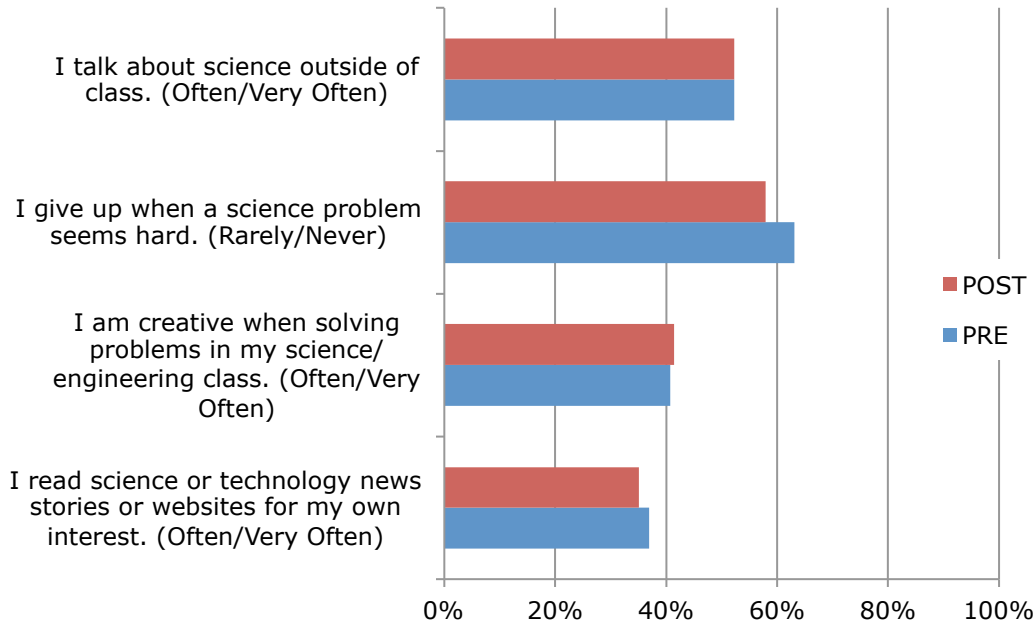
Fall 2014, All ST Courses, N=305



Spring 2015, All ST Courses, N=157

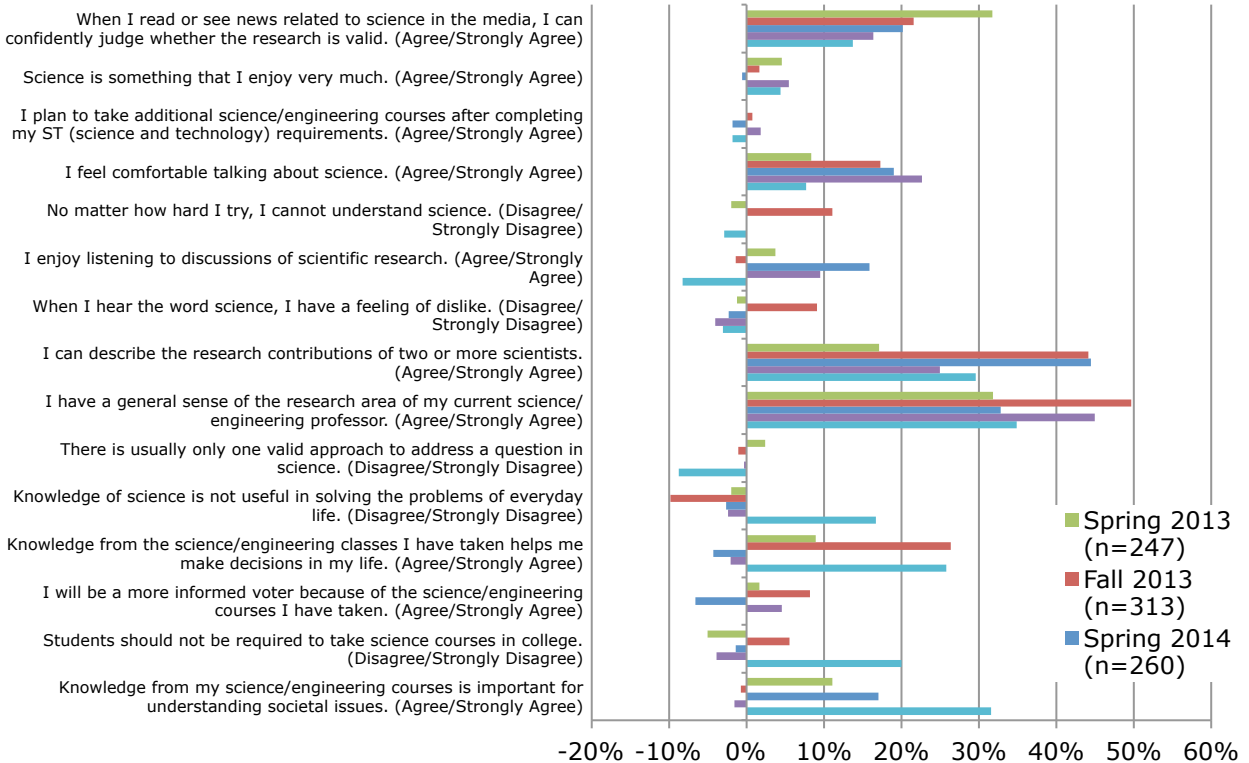


Spring 2015, All ST Courses, N=157

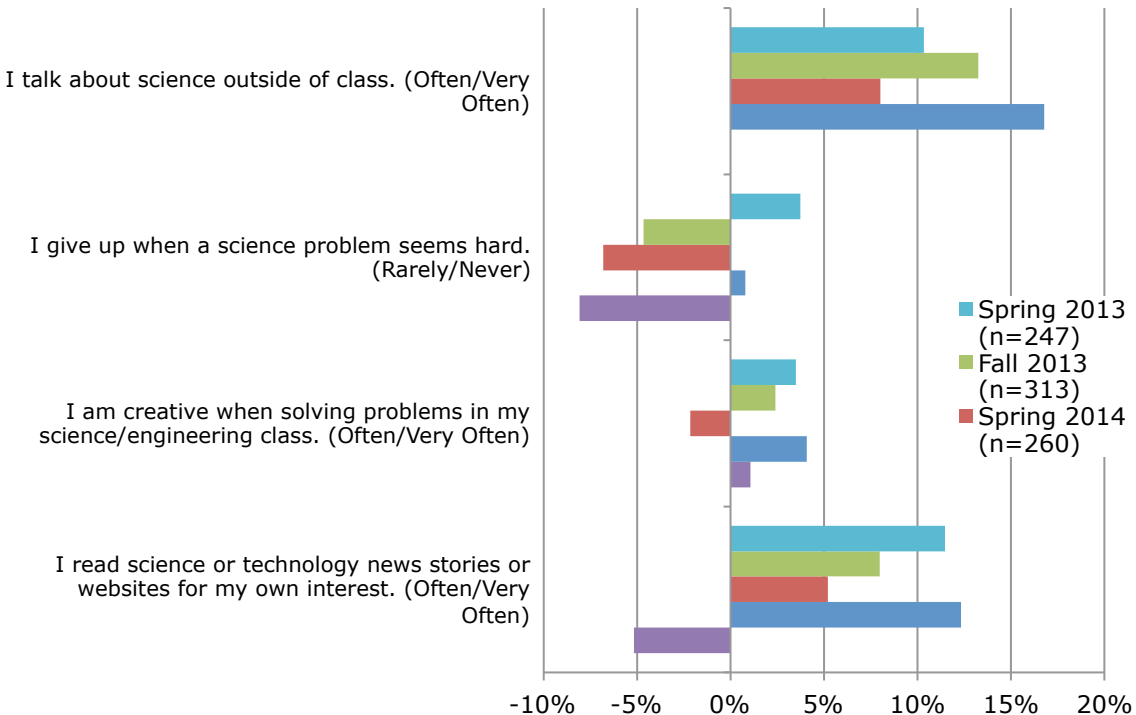


The following two graphs summarize five semesters of attitude results. Positive values are calculated as $\frac{\text{post-semester values} - \text{pre-semester values}}{100 - \text{pre-semester values}}$, or in other words, the improvement normalized by how close the original survey values were to 100% (e.g., a 5% improvement from a starting point of 90% would be normalized to 50%, whereas the same improvement starting at 75% would be just 20%). Negative values are calculated as $\frac{\text{post-semester values} - \text{pre-semester values}}{\text{pre-semester values}}$, or in other words, the improvement normalized by how close the original survey values were to 0% (e.g., a 5% decrease from a starting point of 90% would be normalized to -5.6%, whereas the same decrease starting at 75% would be 6.7%).

Normalized change in attitudes



Normalized change in behaviors



Consistently across semesters, we see improvements in students' confidence in judging science in popular media and in recognizing the research interests and contributions of scientists/engineers. Students also show an increase in their frequency of reading and discussing science/engineering outside of class. Other categories may show smaller improvements or inconsistent results. In general, the positive gains are more prevalent. No statement shows consistently negative change, though some of the negatively phrased statements (i.e., ones for which we track the "Disagree" and "Strongly Disagree" responses) typically have small negative changes; this may be a case of students misreading the statement since the results are inconsistent with similar statements written with a positive sentiment. In general, CST is pleased with the improvements in students' attitudes and behaviors across the semester in which they take ST courses.

III. Educational Research

The Council has launched an educational research agenda focused on understanding the STEM educational experience of undergraduates, as well as the faculty perspective on STEM education at Princeton University. Research findings will assess the impact of the Council, inform future work, and contribute to the growing body of literature on excellent and equitable STEM education. During the 2014-2015 academic year, three research projects were designed and implemented. Data collection and analysis will continue for several academic years. The following subsections describe each of the three current projects.

a. Freshmen Scholars Institute

The Princeton University Freshmen Scholars Institute (FSI) aims to engage a highly motivated community of incoming freshmen in rigorous coursework and meaningful social and professional development. As evidenced by the existing research literature, summer bridge programs like the FSI increase retention and graduation rates, as well as improve students' self-efficacy and social capital. Many of the existing studies of summer bridge programs primarily use quantitative data to draw conclusions. The voices of the participants, who are often first-generation, low-income students, are missing from the literature. To begin to fill these gaps in the literature, CST is conducting a research study on the FSI. The guiding research question is: *As described by the students, what is the lived experience and longitudinal impact of the FSI?* In particular, we are interested in describing the FSI through the students' voices, with a focus on the quantitative reasoning (QR) course and new science and engineering (STL) courses for STEM majors. We are also interested in gaining the students' perspective on the longitudinal impact of the FSI on their persistence in a STEM major, on their overall scientific literacy, and on their overall satisfaction with the undergraduate experience at Princeton University.

b. CEE 262 Structures and the Urban Environment

Students in this course are exposed to fundamental ideas in civil and structural engineering through the great works of pioneering engineers. A central message of this course is that engineering is a creative discipline that allows for creative and aesthetic explorations within constraints. CEE 262 is open to all majors and is offered every spring semester. The course enrolls approximately 150 students each spring semester. The Council developed and implemented a mixed-methods study to evaluate the impact of

the course on students' cognition and affect. Preliminary findings from the study revealed: 89% of students experienced moderate to great gain in interest in engineering; 85% reported moderate to great gain in recognizing engineering as a creative profession; 83% indicated moderate to great gain in understanding how engineering helps people address real world issues; and, on average, 78% of students reported a moderate to great gain in their STEM abilities. Evaluation of the course will be on-going and aligned with the recently awarded National Science Foundation grant (see Synergistic Activities section).

c. Physics 103/104 General Physics

In an effort to enhance the traditional calculus-based introductory physics course, a teaching experiment was undertaken in Physics 103/104 during the 2013-2014 academic year. Specifically, Dr. Katerina Visnjic utilized the Investigative Science Learning Environment (ISLE) curriculum in her labs, while the other sections maintained the labs and pedagogy of previous years. The two key features of the ISLE curriculum are involving students in the development of their own ideas and encouraging students to represent physical process in multiple ways, thus helping them develop productive representations for qualitative reasoning and for problem solving. The Council was invited to explore the cognitive and affective gains for students in Dr. Visnjic's lab. As such, the Council developed and implemented a pilot study during the 2013-2014 academic year. The results of that pilot informed the development and implementation of the 2014-2015 study. The questions guiding the CST study were: *As described by the students, what were the PHY 103/104 course goals? How do students describe the ISLE and traditional labs? To what extent did students relate the physics concepts and procedural skills acquired in PHY 103/104 to their everyday lives?* Preliminary findings from the pilot study were presented at the American Association of Physics Teachers 2015 Summer Meeting.

IV. Synergistic Activities

The Council supports synergistic activities that explore and promote the relation of STEM with culture and the course of public affairs. Activities include workshops, seminars, projects, informal learning opportunities, and events for faculty, post-doctoral fellows, graduate and undergraduate students, and community members. The following subsections describe the Council's 2014-2015 synergistic activities.

a. National Science Foundation Improving Undergraduate STEM Education Grant

Recent reports from the Office of the President of the United States and the National Academy of Engineering urge the nation to increase student retention in science, technology, engineering and mathematics, and to educate a STEM-literate populace. Uninspiring introductory courses, poor teaching, and lack of effective dissemination of best-practices are major obstacles that stand in the way of achieving these goals. Faculty members from Princeton University, Virginia Tech and the University of Massachusetts Amherst are partnering on a project entitled "Advancing the Dissemination of the Creative Art of Structural/Civil Engineering" with the aim of overcoming these obstacles through supporting the dissemination and implementation of an introductory civil engineering course that is to be enhanced with research-based pedagogy. The main objectives of the project are to: (1) transform an introductory engineering course to dramatically improve interactivity and accessibility for non-STEM

students; (2) ensure that the course takes a form that can be readily adopted into the engineering and general education curricula of many types of institutions of higher education (e.g., undergraduate institutions, research universities, etc.); and (3) facilitate dissemination, adoption, and continuous improvement of the courses beyond the audience already being reached. Members of the Council on Science and Technology serve as Co-PI (Evelyn Laffey) and part of the management team (Aatish Bhatia and Laura Sarubbi). Their main responsibilities include leading project evaluation and supporting the infusion of evidenced-based teaching practices into the targeted courses. The project is funded by the National Science Foundation (NSF DUE 14-32426, 14-31717, and 14-31609).

b. STL Courses for the Freshmen Scholars Institute

The Princeton University Freshmen Scholars Institute (FSI) aims to engage a highly motivated community of incoming freshmen in rigorous coursework and meaningful social and professional development. As evidenced by the existing research literature, summer bridge programs like the FSI increase retention and graduation rates, as well as improve students' self-efficacy and social capital. Some of the salient features of summer bridge and first-year engineering experiences that contribute to student success include: using evidenced-based teaching practices, providing opportunities for students to engage in authentic scientific and engineering endeavors early-and-often, and cultivating opportunities to enhance faculty-student interaction. The Council partnered with the FSI management team and faculty in Molecular Biology and Electrical Engineering to assist with the development and evaluation of two new courses: MOL 152 Laboratory Research in the Life Sciences and EGR/STC150 Foundations of Engineering. The development of the courses was informed by existing literature on STEM education and findings from a study conducted by the Council in 2014 (see section III.a.).

c. Summer Institute

The Council supported Prof. Rebecca Burdine (Molecular Biology and Member of CST Executive Committee) in hosting the 2015 Northeast Summer Institute (SI). The Northeast SI welcomed over 45 faculty from diverse academic institutions to Princeton University in June 2015. The Institutes emerged from the 2003 National Research Council report, *Bio2010: Transforming Undergraduate Education for Future Research Biologists*. The report concludes that faculty development is a crucial component of improving undergraduate education. It recommends that universities provide faculty with opportunities to refine classroom techniques and better integrate math and physical sciences concepts into biology instruction. The Summer Institutes bring science faculty and instructional staff together to improve education by integrating current scientific research and pedagogical approaches to create courses that actively engage students in the ways that scientists think. The Summer Institutes provide venues for college and university faculty and instructional staff to meet for intensive discussions, demonstrations, and working sessions on research-based approaches to undergraduate education (<http://www.academiessummerinstitute.org>).

d. Women in STEM Panel and Academic Expo

In welcoming the Class of 2018, the Council on Science and Technology hosted the annual Women in STEM Panel and participated in the Academic Expo during Freshmen Orientation. The Women in STEM Panel was moderated by the Council Director, Prof. Naomi Leonard (Mechanical and Aerospace Engineering). Panel participants included: Abby Doyle (Chemistry), Janine Nunes (Mechanical and Aerospace Engineering), Ilana Witten (Psychology), Jessica Irving (Geosciences), and Lindsey Bergh (Women in Science Colloquium student representatives). During the Academic Expo, members of the Council staff greeted students, shared information, and answered questions.

e. Evinin Lectures

The Evinin Lectures were established with a gift from Anthony B. Evinin to promote a better understanding of the critical roles of science and technology in all aspects of human endeavor. Since 1991, the Council on Science and Technology has invited luminaries in the fields of science, math, engineering and technology to explore topics of interest to a broad audience. These lectures are free and open to the public. The Council hosted an Evinin Lecture during the 2014 calendar year:

- On April 21, 2014, **Keith Devlin**, Stanford Professor and Princeton Visiting Professor of Mathematics, presented *Leonardo and Steve: The Young Genius Who Beat Apple to Market by 800 Years*. The first personal computing revolution took place not in Silicon Valley in the 1980s but in Pisa in the 13th Century. The medieval counterpart to Steve Jobs was a young Italian called Leonardo, better known today by the nickname Fibonacci. Thanks to a recently discovered manuscript in a library in Florence, the story of how this little known genius came to launch the modern commercial world can now be told. The lecture was co-sponsored by the McGraw Center for Teaching and Learning.

f. Co-Curricular and Informal Learning Experiences

With the intent of promoting and celebrating the role of STEM in society, the Council supported the following co-curricular or informal learning experiences:

- In co-sponsorship with the Keller Center for Innovation in Engineering Education, the Council supported two undergraduate students (a computer science major and a music major) for an informal learning opportunity with Jeff Snyder (Music Department). The purpose of the project was to explore how hardware and software design can relate to the arts and culture. The students worked directly on the development and release of a new electronic wind instrument for professional musical performance. The students worked closely with the case study users (five professional musicians) over the summer to understand the needs of performers and then used their feedback to guide development. The goal of the instrument is to appeal to musicians from multiple genres of music, so gaining an understanding of the needs of these different musical cultures was important to the process.
- In co-sponsorship with the Office of Sustainability, the Council supported two undergraduate students for a summer internship. The students engaged in a mapping project that documented the history, environment, and people of Princeton University. The students worked closely with Catherine Riihimaki (CST), Shana Webber (Sustainability), the Campus 2026 Planning Team, and

various other University departments and units. They developed a 40-page guidebook that documents their spatial analysis of the campus' evolution from 1756 to 2015.

g. Conferences, Committees & Presentations

A number of Council faculty and staff attended relevant national and regional conferences. These conferences offered excellent professional development and learning opportunities, as well as venues to share the work of the Council. A few examples of conference attendance and presentations are as follows:

- Catherine Riihimaki presented: Riihimaki, C. A., Caylor, K.K., and Wilcove, D. S. (2014), *Planetary boundaries and environmental citizenship: enhancing environmental science through the Princeton University Science and Engineering Education Initiative* at the American Geological Union Fall Meeting in San Francisco, CA.
- Aatish Bhatia presented: Bhatia, A., Chen, P.C., Garlock, M., & Laffey, E. (2015). *Active Learning Pedagogies Promoting the Art of Structural and Civil Engineering* at the 122nd American Society for Engineering Educators Annual Conference and Exposition, Seattle, WA.
- Evelyn Laffey presented: Laffey, E.H., Houck, A.A., Gmachl, C., and Duvvuri, V. (2015), *Foundations of Engineering: A credit-bearing course for the Princeton University Freshmen Scholars Institute* at the First-Year Engineering Experience annual conference in Roanoke, VA.
- In April 2015, Evelyn Laffey and Prof. Catherine Peters attended the AAU STEM Education Initiative Workshop for Department Chairs in Washington, DC.
- In July 2015, Jaclyn Schwalm attended the Society for the Advancement of Biology Education Research (SABER) meeting in Minneapolis, MN. editorship

The Council participated in university-wide committees and strategic planning taskforce. The committees included: Committee on Classrooms and the Schedule, Green Hall Active Learning Committee, Academic and Administrative Management Group, and the School of Engineering and Applied Sciences Taskforce on the Undergraduate Curriculum. Committees outside of the University include the New Jersey Higher Education Partnership for Sustainability and the AAU STEM Education Initiative Network.

V. Summary and Looking Ahead...

CST continues to serve the University by catalyzing and supporting intellectual exchange, interdisciplinary research, excellent courses, and multidisciplinary collaboration that broaden participation in and appreciation of science, technology, engineering and mathematics (STEM). As originally mandated, CST engages a broad audience in meaningful STEM experiences. Currently, CST aims to understand the dynamic nature of STEM education in the 21st Century and provide diverse opportunities to engage members of the Princeton University community.

In looking ahead, CST will continue to advance the programmatic initiatives described above and complement the portfolio of activity with the following:

- *StudioLab* - The CST creative space will be both studio and laboratory, serving as a flexible environment for exploring, teaching, collaborating, and creating at the intersections of STEM with the Arts, Humanities, and Social Sciences. We envision that the space will stimulate and accommodate innovative classes and labs, workshops and informal learning opportunities, cross-disciplinary research and intellectual exchange, educational research, student run initiatives, and more.
- *Faculty Perspectives* - CST is embarking on a research study to understand the lived experiences of Princeton faculty teaching STEM courses and/or interdisciplinary courses with some STEM content. We're interested in defining "STEM education for the 21st Century" with attention given to the dynamic roles of faculty in higher education.
- *CST and Humanities Council Faculty Seminar* – Plans are underway to offer a monthly gathering of faculty from the humanities, natural and social sciences and engineering to jointly explore a topic of mutual interest.
- *CST/Writing Center STEM Ambassadors* – Jointly appointed undergraduate student Writing Fellows who provide peer-mentoring on writing assignments in the ST-designated courses that the Council supports.
- *CST Undergraduate and Graduate Student Ambassadors* – A diverse group of students who develop and implement programming aligned with the Council's desire to explore the intersections across STEM, the humanities, social sciences, and the arts.
- *Panels with the Princeton University Art Museum* – Faculty from various divisions discuss a piece of art from their disciplinary perspective.

The primary focus of CST initiatives is to explore and promote the intersections and shared creativity across STEM, the arts, the humanities and social sciences. CST initiatives will continue to inform practice: new courses will emerge from supported research; multidisciplinary discussions will inform new research agendas and courses; rigorous evaluation on cognition and affect will inform educational practice.

Appendix A – Case Studies of Courses Supported by CST Professional Specialists

Dr. Aatish Bhatia worked with several courses during the 2014 – 2015 academic year, and contributed to two ongoing educational research projects. Highlights from three of these projects are described in the following case studies.

CEE 262: Structures in the Urban Environment, taught by Prof. Maria Garlock.

Students in this course are exposed to fundamental ideas in civil and structural engineering by examining the great works of pioneering engineers, as well as the societal and historical factors that led to these developments. A central goal of this course is for student to appreciate that engineering is a creative discipline.

CST is a co-awardee of a multi-institutional NSF Improving Undergraduate STEM Education (IUSE) grant for an education research and dissemination project entitled ‘*The Creative Art of Structural and Civil Engineering*’, whose goals include to significantly enhance the interactivity of this course by adopting evidence-based teaching practices such as active learning, and to facilitate the dissemination and adoption of these course materials to a wide array of institutions.

Aatish has continued to work with CEE 262 as a course consultant, and as part of the IUSE grant, where his roles have included assisting with the following:

1. Developing, implementing and documenting active learning exercises, such as clicker questions and interactive lecture demonstrations, and developing material for a new lecture on Engineering Ethics
2. Developing and synthesizing learning goals and lecture objectives
3. Organizing course material into modules for online dissemination
4. Developing and implementing surveys to assess learning goals, student affect, and student attitudes towards engineering
5. Facilitating a workshop of engineering educators at Princeton University to disseminate course material
6. Presenting a conference talk and publishing a proceeding to disseminate course material at ASEE 2015

Additionally, he has contributed to STEM engagement to a broad audience by developing widely-read online articles on some of the concepts and themes discussed in this course:

<http://www.wired.com/2014/09/curvature-and-strength-empzeal/>

<http://www.wired.com/2015/03/empzeal-eiffel-tower/>

STC349/ENV349: Writing about Science taught by Michael Lemonick. This is a seminar designed to teach students of all majors how to write about science in a manner that is accessible and engaging to a wide audience. This course aims not only to help students develop an understanding of scientific results, but also to provide their context, and to critically examine the nature of the scientific process.

In Fall 2015, Aatish worked closely with Michael Lemonick to broaden the focus of the course to include discussions on the role of statistics in science and science journalism. The goals of these discussions were to help students:

1. Critically evaluate claims made in press releases and popular science articles
2. Develop their ability to parse a scientific paper and assess the significance of the results
3. Develop their awareness of ways that statistics can be misused/misinterpreted
4. Responsibly report on scientific results by avoiding hype and communicating the limitations of a given study

To this end, Aatish led workshop activities where students read claims in press releases or in popular science articles, and then went back to the primary literature to seek evidence to support these claims. He also led discussions on the role of statistics in science and science journalism, to help students become well-informed science communicators and readers of the scientific literature. These discussions covered topics such as the phenomenon of “p-hacking”, the importance of considering the effect size and sample size of a given finding, and the need to appropriately correct statistics when multiple comparisons are being made. He also discussed with the students the essential elements of science blogging, and worked with the instructor to introduce a new blogging assignment, where students wrote a science blog post on a recent research finding.

EGR/STC 150: Foundations of Engineering, taught by Prof. Claire Gmachl and Prof. Andrew Houck.

This is a new course developed for the Freshman Scholars Institute in Summer 2015. Aatish collaborated with the faculty of this course, consulting on the following roles:

1. Developing and helping to implement active learning exercises such as clicker questions
2. Providing feedback to the teaching team and working with the course fellows, FSI administration, and Geneva Stein in McGraw to help ensure that the students were engaged in the course and understanding the course concepts
3. Facilitating discussions with students on physics and calculus concepts in workshop sessions
4. Collaborating on a multi-year study of students and faculty in the Freshman Scholars Institute, exploring how this program impacts students' college experiences. In summer 2015, this consisted of:
 - a. Developing and implementing concept inventories to assess student's understanding of physics and calculus concepts
 - b. Interviewing students and faculty on their FSI experiences and perspectives

The following video developed by the Office of Communications highlights the bottle rocket launch, a key component of this course: <https://vimeo.com/136638293>

Dr. Catherine Riihimaki worked with several courses during the 2014 – 2015 academic year. Highlights from four of those courses are described in the following case studies.

ENV201: The Fundamentals of Environmental Studies: Population, Land Use, Biodiversity, and Energy, taught by Prof. David Wilcove from WWS/EEB and Prof. Kelly Caylor from CEE, is aimed at students interested in the combination of environmental science and policy. In Fall 2014, CST facilitated several revisions to the course to improve student engagement in lecture and precept, to build critical skills for analyzing environmental issues in the news, and to increase feedback to the students on their progress toward learning skills and concepts. Specific changes included

- 1) Experimentation with more in-class questions, discussions, and activities, such as debating organic versus conventional agriculture based on a Stanford University study and exploring global environmental data using Google Public Data Viewer (<http://www.google.com/publicdata/directory>);
- 2) Development of a new precept activities based on the questions: what are the important concepts this week, what concepts will they struggle with and therefore need more time to digest, and what specific data can we have them examine that will help them deal with the concepts in a rigorous way and that they can use to demonstrate deep understanding; data have included campus-specific data on energy consumption, personal data from their lives (e.g., descriptions of their diets from the few days before precept), data collected in a whole-class tragedy-of-the-commons game, and data sets from homework readings;
- 3) Development and assignment of weekly precept homework, allowing the students to practice course concepts in context and to receive regular feedback from preceptors;
- 4) Creation of a mid-semester evaluation for students to provide feedback on the course; and
- 5) Creation of a survey of the class to reflect on how this course has impacted their optimism about our ability to solve environmental issues discussed in the course.
- 6) CST teaching specialist Catherine Riihimaki continued to be the lead lab instructor for the course, including the development of a lab exercise at the Princeton University Art Museum looking at whether historic art can be used to reconstruct past environmental conditions.

The outcomes of these changes were positive, with course evaluation scores significantly higher than in Fall 2012.

FRS125: The Science and Art of Mapping the World was developed and taught by Dr. Riihimaki in Fall 2014. This course enabled students to explore fundamental concepts of geography, including coordinate systems, data organization systems, and data interpretation strategies; apply basic graphic design concepts to create compelling maps and graphics for presenting spatial data; apply quantitative spatial analyses to applied projects in a variety of fields, including public health, political science, environmental science, and economics; and become proficient with ArcGIS software capabilities and limitations, and discuss the benefits and limitations of freeware mapping applications. Students worked on weekly mapping assignments that built to a culminating final project in which they developed their own research question, found or created relevant data, and interpreted the results, and designed a poster to share their projects with classmates. Multiple students pursued internships in Summer 2015 involving mapping and/or data analysis, stemming from the skills learned in this course.

WWS350: The Environment: Science and Policy, taught by Prof. David Wilcove from WWS/EEB and Prof. Michael Oppenheimer from WWS/GEO, returned from a hiatus in Spring 2014 to be offered for its second time in Spring 2015. The course was significantly changed from its initial offering in Spring 2013, because Prof. Oppenheimer replaced Prof. Denise Mauzerall on the teaching team. This led to changes in the course topics, including greater emphasis on the process of creating and implementing effective environmental policies at the domestic and international level, and more analysis of climate science and policy. Course topics were developed in consultation with Dr. Riihimaki, and she assisted in developing weekly precept homework assignments, precept discussion topics, and exam questions. Dr. Riihimaki also oversaw the preceptors, meeting with them weekly to discuss teaching strategies and issues and to ensure that the preceptors had clear and consistent learning goals for their students. The result was student course evaluations that improved in the Overall Quality of the Course rating by 0.78 points, and the Precepts rating as the highest category. CST work will continue with this course in Spring 2016, as Dr. Jin Sato, a visiting fellow in East Asian Studies, will replace Prof. Oppenheimer on the teaching team, necessitating another revision of course topics, assignments, and assessments.

ENE202: Designing Sustainable Systems - Applying the Science of Sustainability to Address Global Change, taught by Prof. Forrest Meggers from ARC and Andlinger Center, was taught for the second time in Spring 2014. It combines environmental science and design concepts to help students develop creative solutions to environmental problems such as transportation inefficiencies, excess waste production, and overuse of electricity. CST helped Dr. Meggers refine learning goals and teaching strategies for the class, and administered a mid-semester survey to determine how the students were responding to the course. Student evaluations indicate significant improvement in the course, particularly in aligning the first and second halves of the course. CST will continue to work with Dr. Meggers as he works to convert this one-time-only course into a permanent course.

Dr. Jaclyn Schwalm worked with several courses during the 2014 – 2015 academic year. Highlights from two of those courses are described in the following case studies.

MOL101: From DNA to Human Complexity: taught by Profs. Eric Wieschaus and Bonnie Bassler, and Senior Lecturer Heather Thieringer

In the 2012-2013 academic year, in collaboration with one of our staff members, the instructors of the MOL101 course, which is composed almost exclusively of students majoring in the humanities or social sciences, began to incorporate more student-active pedagogy into the course. In the 2013-2014 and 2014-2015 academic years, this work was continued and expanded.

The course was taught in the Frist Campus Center Multipurpose Room in both the 2013-2014 & 2014-2015 academic years, which allowed groups of students to sit at round tables and work collaboratively throughout the course. The flat classroom space also allowed instructors and assistants in instruction to circulate, working with students in small groups during these collaborative activities. In addition, a student-response system has been used throughout the course since the 2012-2013 academic year, allowing the students to use clickers to answer questions to check their own understanding, and

allowing the instructors to determine whether students were understanding the material in real-time. Each year, the use of this system has been continued and expanded.

In addition to the use of collaborative work and student-response systems in class throughout the course, learning goals have been incorporated into the course and students have been asked to complete pre- and post-class assignments. The learning goals have helped the students to develop a better understanding of the course expectations, and the assignments have helped the students to understand and review the concepts taught in class. The assignments have also helped the instructors to identify concepts about which students were particularly confused so that these areas of confusion could then be addressed in class. Student performance on these assignments has been highly correlated with their performance on exams, suggesting that the assignments have been accomplishing their intended purpose.

MOL380: Modern Microbiology and Disease, taught by Dr. Jaclyn Schwalm, has traditionally been taught as an every-other-year course that was completely revamped (lectures, precepts, and laboratory) for the 2014-2015 academic year. This course fills a variety of roles for both the MOL Department and other programs. It has been approved as an elective in the Global Health and Health Policy Program. The course seeks to foster an understanding of the molecular processes through which microbial organisms function and cause disease, as well as develop an appreciation for both the positive and negative effects of microbial organisms on our daily lives. The enrollment in the 2014-2015 academic year was approximately 35% MOL majors and 65% non-majors, approximately 26% of these were social science or humanities majors. A variety of evidence-based teaching practices were incorporated into this course: collaborative work and interaction throughout lectures, a student-response system, weekly short problem sets, learning goals, inquiry-based laboratories, and a mid-semester evaluation, among other assignments and practices. Student evaluations for the revamped version of the course were extremely positive, and the intention is for the course to be offered in future years.

Dr. Carolyn Sealfon worked with several courses during the 2014 – 2015 academic year. Highlights from four of those courses are described in the following case studies.

PHY 115: Physics for Future Leaders, taught by Prof. Paul Steinhardt

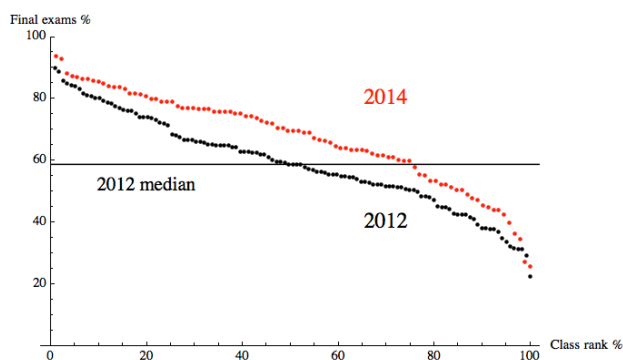
Goal: Designing assignments and activities that increase transfer of learning (e.g., to everyday life). Seeking to combine virtues of the 2011 final project (making comparisons among scientific projects in a realistic roleplaying scenario) and the 2012 final project (applying PHY 115 concepts to evaluate technologies directly relevant to students' lives), we assigned students to evaluate and compare projects from crowdfunding websites (such as Kickstarter). Each student was assigned two inventions from an actual crowdfunding site, and provided with several guiding questions (qualitative and quantitative) to apply their learning from PHY 115 to evaluate and compare the feasibility of the projects. They were then asked to find a third crowdsourcing project on their own that they thought was better than the other two, and come up with their own questions to apply PHY 115 material to evaluate its feasibility.

PHY 102: Introductory Physics taught by Prof. Steve Gubser

Goal: Increasing professor-student feedback through formative assessment activities

Prof. Gubser created weekly pre-class video lectures covering material from each week's assigned chapter, which he posted on Coursera. We interspersed each video lecture with 5-10 conceptual and quantitative multiple-choice questions, based on physics education research where possible, for students to check their understanding and for Prof. Gubser to see what students were getting wrong before lecture. Lectures were primarily focused on interactive demonstrations, for which students would use clickers to make predictions about outcomes (since research shows that this enhances student learning from demonstrations). Significant time in precepts was devoted to students working in assigned groups through packets of physics problems.

Prof. Gubser gave a final exam that was roughly isomorphic to an exam he gave two years ago, and found a significant gain in student learning:



Comparison of exam scores, courtesy of Prof. Gubser

We estimate the error due to differences in graders to be about 3 points, which is much less than the overall difference in exam scores of about 9 points.

PHY 103-104: General Physics, Select Precepts/Labs taught by Dr. Katerina Visnjic

Goal: Changing the classroom dynamic from teacher-centered to student-centered

To assist with piloting ISLE (Investigative Science Learning Environment) labs in PHY 103-104, we held weekly meetings with the graduate Assistants in Instruction for the experimental sections. We discussed articles or results from physics education research about common student challenges with the coming week's material and strategies to address them, as well as reflected on the past week, discussed what went well, and brainstormed solutions to unexpected challenges that arose.

Appendix B – ST-Designated Courses that Aligned with the Science and Engineering Education Initiative

Fall 2014 – 2015

STL Courses – Science and Technology with Lab

ANT 215	Human Adaptation
CEE 102B	Engineering in the Modern World
EEB 211	The Biology of Organisms
EEB 417B	Ecosystems and Global Change
ENV 201B	Fundamentals of Environmental Studies: Population, Land Use, Biodiversity, and Energy
FRS 133	Materials World
FRS 134	Global Warming and Ocean Environments
MOL 101B	From DNA to Human Complexity
PHY 101	Introductory Physics I
PHY 115B	Future Physics
PSY 101	Introduction to Psychology

STN Courses – Science and Technology without Lab

AST 201	Mapping the Universe
AST 205	Planets in the Universe
CEE 334	Global Environmental Issues
ENV 201A	Fundamentals of Environmental Studies: Population, Land Use, Biodiversity, and Energy
FRS 109	Water: Keystone for Sustainable Development
FRS 125	The Science and Art of Mapping the World
FRS 127	The Smart Band-Aid
MAE 228	Energy Solutions for the Next Century
NEU 258	Fundamentals of Neuroscience
PHY 115A	Future Physics

Spring 2014 - 2015

STL Courses – Science and Technology with Lab

CEE	262B	Structures and the Urban Environment
ENV	340	Environmental Challenges and Sustainable Solutions
FRS	106	Art and Science of Motorcycle Design
GEO	103	Natural Disasters
GEO	202	Ocean, Atmosphere, and Climate
PSY	101	Introduction to Psychology

STN Courses – Science and Technology without Lab

AST	204	Topics in Modern Astronomy
EEB	301	Evolution and the Behavior of the Sexes
EEB	311A	Animal Behavior

FRS	110	Personal Genomes, Medicine and Algorithms
FRS	124	The Everglades Today and Tomorrow: Global Change and the Impact of Human Activities on the Biosphere
FRS	136	Emerging Micro and Nano-Engineered Technologies
FRS	144	How the Tabby Cat Got Her Stripes
FRS	152	Drug Discovery: From Snake Venoms to Medicines
FRS	162	Water: Keystone for Sustainable Development
FRS	166	Why Global Warming is Controversial
WWS	350	The Environment: Science and Policy